demand, depending on the type of compensation filter 192 that is employed. The power amplifier 196 drives the electromagnet 182 to produce the desired flux 178, and hence the appropriate force on the support structure 16.

The present invention may be used to control a wide variety of industrial and other structures, including a complex piping system 210 (FIG. 4), where turbulent fluid 211 flows through an extended pipe 212. The system shown in FIG. 4 has multiple vibration sensors 32, 34, 214, 216, 218 for feeding vibration data to the digital controller 30 via suitable signal lines 52, 54, 220, 222, 224. In addition, the system 210 has an environmental sensor 40 for sensing characteristics of the variable state of the pipe 212. In the illustrated embodiment, the environmental sensor 40 is arranged to sense the mass flow rate of the fluid 211 through the pipe 212. Other environmental data that may be supplied to the controller 30 includes fluid pressure, temperature, etc. The controller 30 receives the input data with respect to vibration of the controlled structure 212, vibration of a feedforward reference (not shown in FIG. 4), and the variable state of the pipe 212, and applies appropriate signals to the electromagnets 182 of multiple actuators 74, 76. Thus, the operation of the control system 30 in the FIG. 4 embodiment is similar to its operation in the FIGS. 1 and 2 embodiment.

The above descriptions and drawings are only illustrative of preferred embodiments which achieve the features and advantages of the present invention, and it is not intended that the present invention be limited thereto. Any modification of the present invention which comes within the spirit and scope of the following claims is considered part of the present invention.

What is claimed as new and desired to be protected by Letters Patent of the United States is:

1. A low-frequency vibration control system, comprising:

an electromagnetic actuator for selectively applying forces to a controlled structure, said actuator consisting essentially of an armature, a magnet coil and a flux sensor; and

a digital control system for causing a force-linearized flux to be generated in a gap between said armature and said magnetic coil, as a function of sensed vibration; and

wherein said flux sensor sends signals to said digital control system representative of the flux generated in said gap between said armature and said magnetic coil.

2. The vibration control system of claim 1, wherein said magnet coil is integrally fixed to said controlled structure.

3. The vibration control system of claim 2, wherein said flux sensor is connected to said magnet coil.

4. A vibration control system for a variable-state structure, said system comprising:

electromagnetic actuators for selectively applying forces to said variable-state structure; and

a digital control system for operating said actuators as a function of sensed vibration of said variable-state structure, sensed vibration of a feedforward reference, and the variable state of said variable-state structure.

5. The vibration control system of claim 4, further comprising vibration sensors for sensing the vibration of said variable-state structure.

6. The vibration control system of claim 5, wherein said digital control system includes modal feedback loops for controlling said actuators in response to signals from said vibration sensors.

7. The vibration control system of claim 6, wherein the gains of said modal feedback loops are controlled as a function of the variable state of said variable-state structure.

8. The vibration control system of claim 4, further comprising one or more feedforward sensors for sensing vibration of feedforward references.

9. The vibration control system of claim 8, wherein said digital control system includes one or more feedforward loops for controlling said actuators in response to signals from said feedforward sensors.

10. The vibration control system of claim 9, wherein the plant transfer functions of said feedforward loops are controlled as a function of the variable state of said variable-state structure.

11. The vibration control system of claim 10, further comprising a position sensor for sensing a variable position of said variable-state structure.

12. The vibration control system of claim 10, further comprising a device for inputting data representative of the mass of said variable-state structure.

13. A method of controlling vibration of a variable-state structure, said method comprising the steps of:

obtaining first data representative of the vibration of said variable-state structure;

obtaining second data representative of variable mechanical characteristics of said variable-state structure; and

selectively applying electromagnetic forces to said variable-state structure as a function of said first data and said second data.

14. The method of claim 13, further comprising the step of operating a feedforward loop based on a fixed-frequency reference that is external to said variable-state structure.

15. The method of claim 14, further comprising the step of changing the plant transfer function estimates of said feedforward loop as a function of said second data.

16. The method of claim 15, further comprising the step of changing the characteristics of said feedforward loop as a function of said first data.

17. The method of claim 16, further comprising the step of operating modal feedback loops based on said first data.

18. The method of claim 17, further comprising the step of changing the gain of said feedback loops as a function of said first data.

19. A vibration control system, comprising:

an actuator for applying a force to a variable-state structure, said actuator including an electromagnet, an armature and a magnetic flux density sensor, and wherein said magnetic flux density sensor is operatively located so as to sense the magnetic flux between said electromagnet and said armature;

a data input device for inputting data representative of the variable state of said variable-state structure; and

a processor for applying signals to said electromagnet, said processor being operatively connected to said data input device and said magnetic flux density sensor.

20. The vibration control system of claim 19, wherein said processor is arranged to calculate the difference between the flux density sensed by the magnetic flux density sensor and the flux density required in the actuator to control vibration of the variable-state structure.

21. The vibration control system of claim 20, wherein said electromagnet is integrally connected to said variable-state structure, and said armature is integrally connected to an external structure.

22. The vibration control system of claim 21, wherein said electromagnet is sealed to prevent degradation by fluids and dust.